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INTERSENSORY FACILITATION IN A GO/NOGO AND A CHOICE REACTION TIME TASK

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In a visual reaction time (RT) task, RT was shortened when an auditory stimulus was presented at approximately the same time. Such the auditory stimulus is called an accessory because subjects need not attend to it to perform the task. This study examined whether magnitudes of this intersensory facilitation between the visual target and the auditory accessory can be changed by types of the RT task. The magnitudes of facilitation (MF) was RT differences between with- and without-accessory trials. This experiment compared MFs between a Go/Nogo task and a choice reaction time (CRT) task. In the former task subjects execute a motor response or withhold it, while in the latter they must choose left or right hand response. Results showed that the MF was increased as the accessory preceding the visual target as far as the two stimuli were presented at approximately the same time. The MFs were significantly larger in the Go/Nogo task than in the CRT task. The MFs showed the maximum value when the accessory preceded the visual target by a few hundred milliseconds. These maximum MFs, however, did not differ between the two tasks. Such the results indicated that under the Go/Nogo requirement, the auditory accessory exerted the maximum effect on RT even when it was close to the visual target, but the type of RT tasks did not affect on the maximum MF.

Key words: intersensory facilitation, Go/Nogo task, choice reaction time task, logistic function.

INTRODUCTION

In a visual reaction time (RT) task RT is reduced by a simultaneous or near simultaneous auditory stimulus. This phenomenon is called intersensory facilitation (Bernstein, 1970). This case is true even when subjects are told that they need not attend to the auditory stimulus. Such the stimulus is an "accessory" because it is irrelevant to the task performance. The magnitude of facilitation (MF) by the accessory stimulus usually indicates the difference in RT between the with- and without accessory trials. MFs were varied by some experimental conditions, such as stimulus intensity, onset asynchrony between the visual and the auditory stimulus, or foreperiod (FP) from a warning signal to the presentation of a visual target.

Bernstein, Clark, and Edelstein (1969a,b) showed MFs in two types of RT task. In a Go/Nogo task, subjects choose either a key press or no response, while in a choice RT (CRT) task they choose left or right forefinger response. In both the tasks they must respond as quickly as possible. These experiments showed that the maximum MF was considerably greater in the Go/Nogo task (40.7 msec) than in the CRT task (17 msec). On the basis of these findings,

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Nickerson (1973) inferred that the auditory accessory exerted a larger effect on visual RT in the Go/Nogo task than in the CRT task.

Although Bernsteins' studies demonstrated the difference in the maximum MF between the two tasks, two issues remained to be solved before concluding that. First is the stimulus onset asynchrony (SOA) between the visual target and the auditory accessory. In Bernsteins' experiments, either the two stimuli were presented simultaneously (SOA = 0 msec) or the accessory followed the visual target, and they did not present the accessory preceding the visual target. Nickerson (1973) regarded the MFs at 0 msec SOA as a maximum facilitation. These MFs, however, did not expressed the true maximum facilitation. Because many studies showed that the MF continued to increase and reached the maximum facilitation when the accessory was presented before the visual target (Nakano, 1995; Nickerson, 1970; Posner, 1976). In Nickerson (1970) the RT began to be decreased when the accessory presented 200 msec after the visual targeted. This decreased tendency was demonstrated until the accessory preceded 100 msec by the target. At this SOA point the RT was most facilitated and the maximum facilitation maintained for a few hundred milliseconds in SOA. A similar relationship between the MF and SOA was also indicated in other studies (Nakano, 1995; Posner, 1976). The most important thing is that in Bernsteins' experiment the maximum facilitation was obtained at 0 msec SOA. As noted above, however, the visual RT continued to be decreased at this SOA and did not reach the maximum facilitation. Therefore, on the basis of Bernsteins' results we can not compare true maximum MFs between the Go/Nogo task and the CRT tasks. The purpose of this study is to show the true maximum MF when the accessory presented before the visual target, and to compare it between the two tasks.

A second issue resided in settings of FP that was a temporal interval between the warning stimulus and the visual target. In the Go/Nogo task (Bernstein, 1969a) the FP was randomized in two of three subjects, while in the CRT task (Bernstein, 1969b) it was at constant 2 sec in all subjects. This discrepancy about the FP setting makes us difficult to compare the MFs between the two experiments. This is because the MF is larger in longer or randomized FPs than in shorter or fixed FPs (Bernstein, Chu, Briggs, & Schurman, 1973; Sanders, 1980). Thus the randomized FP in the Go/Nogo task possibly produced the larger facilitation effect than in the CRT task. The present experiment was conducted by using randomized FPs to minimize the unpredictable influence by FP settings.

Method

Subjects: Eight non-paid volunteers (5 female and 3 male) in Tohoku University, ages 20-27 years (mean age = 21.9, *SD* = 1.8) participated in this experiment. They were all right handed with no visual, auditory, or motor handicaps.

Procedure: The experiment was conducted in a dimly-lit, sound-attenuated room. The apparatus for visual stimulation consisted of three light emitting diodes (LEDs) that was located vertically on a black panel. At the center of the panel a red LED was set as a fixation point. On 1 centimeter above and below the fixation point, a green LED was arranged respectively.

They served as a visual target. The subjects observed these stimuli from a distance of 50cm, so the visual angles between the fixation point and the green LEDs were 1.15 deg, respectively. Brightness of all the LEDs was 5 cd/m^2. The subjects rested the chin on a chin support so that the fixation point constantly located on their horizontal straight-ahead line of sight. They had their index fingers resting on two telegraph keys that were situated in front of them.

Each trial began with the warning sound through the headphone, then the fixation point was illuminated. There was a random FP lasting from 1.8 to 2.5 sec between the presentation of the fixation and the visual target. In the Go/Nogo task the upper green LED was illuminated for 10 msec. The subjects were instructed to respond as quickly as possible to the onset of the light by pressing a right hand key. On one sixth of all trials this visual target was not illuminated, these trials served as a catch trial. In this case the subject had to withhold the key pressing. In the CRT task, either of the upper or lower LED was illuminated. Half of the subjects were instructed to press the right key to the upper light and press the left to the lower one as quickly and accurately as possible. The other half of the subjects were given the reverse instructions about the stimulus-response assignment. Two seconds after the presentation of the visual target, the fixation point was disappeared. There was a 2 sec interval before the beginning of the next trial.

At the temporal proximity to the onset of the visual target an auditory accessory stimulus (80 dB, 1000 Hz) was presented through the headphone. The duration of this tone was 80 msec. The subject told that he could ignore it. The stimulus onset asynchrony between the onset of the visual target and the auditory accessory ranged from -400 msec to 300 msec. A negative value indicated that the accessory preceded the visual target. Fourteen SOAs (-400, -300, -200, -100, -75, -50, -25, 0, 25, 50, 75, 100, 200, 300 msec) and a no sound condition were used with equal probability. Timing of stimulus sequences and RT recordings were controlled by PC9801-VX (NEC) personal computer.

The subjects took part in four sessions, one on each of 4 separate days. The half of the sessions were assigned to the Go/Nogo task, and another half were the CRT task. Their order was counter balanced across the subjects. The session consisted of 7 blocks of 50 trials assigning the first block for practice. Totally, 33 or 34 trials (excepting the catch trials) in the Go/Nogo task and 40 trials in the CRT task were obtained at each SOA point as RT data. The session lasted about 30 min, and the subjects took a short break of 1 min between blocks.

Results

RTs shorter than 50 msec (caused by anticipation) or longer than 600 msec (caused by inattention), responses in Nogo trials in the Go/Nogo task or in the incorrect direction in the CRT task were considered as an error. Fig. 1 and Table 1 indicated averaged RTs and *SD*s as a function of SOA in the two tasks. The horizontal solid line indicated the mean RT to without-accessory trials for the Go/Nogo task, and the dashed line indicated that for the CRT task. An RT difference between with- and without-accessory trials was computed at each SOA point. These data served as a magnitude of facilitation (MF) which denotes the effectiveness of the auditory accessory. The negative MF indicated that the RT was shortened by the accessory.

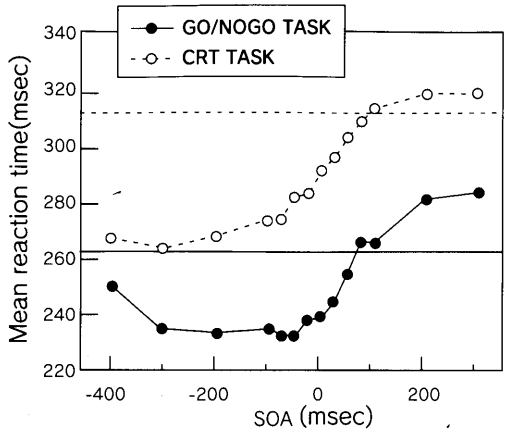

Fig. 1. Mean reaction times as a function of SOA. A horizontal solid line indicates a mean RT to without-accessory trials for the Go/Nogo task, and the dashed line is that for the CRT task.

Table 1. Mean reaction times and *SD*s (msec) as a function of SOA for the Go/Nogo task and the CRT task.

SOA	Go/Nogo Task	*SD*	CRT Task	*SD*
-400	250.0	19.5	267.2	15.7
-300	235.1	12.2	264.1	13.0
-200	232.9	11.2	267.8	14.8
-100	235.0	10.0	273.5	16.5
-75	233.2	9.7	274.2	16.4
-50	233.1	11.1	281.4	13.6
-25	238.1	15.8	283.0	20.3
0	239.6	15.9	291.3	16.6
25	244.5	12.1	295.3	21.7
50	254.8	18.2	302.4	21.3
75	265.7	18.0	308.3	23.2
100	265.3	17.9	312.2	24.4
200	281.0	19.9	318.6	22.6
300	283.4	19.9	318.9	22.4
NS	278.5	20.1	316.9	24.9

Note. Values in NS denotes mean RTs in without-accessory trials.

Figure 2 and Table 2 depicted the MFs at each SOA point for the two tasks. A two-way within-subject ANOVA was performed on the MFs with factors of type of task (Go/Nogo task vs. CRT task) and SOA. The effect of SOA was highly significant, $F(13,91) = 34.9, p < .001$, while there was no significant difference of the MF between the Go/Nogo task and the CRT task,

$F(1,7) = .60$, $p > .1$. The interaction between the type of task and SOA was significant, $F(13,91) = 7.54$, $p < .001$. Post hoc testing of this interaction revealed that the MF was different between the two tasks at some SOA points. As indicated in Table 2, the effect of the accessory was significantly larger (MF was negatively larger) at -50, 0, 25, 50 and 100 msec in the Go/Nogo task than in the CRT task. This relationship was reversed only at -400 msec SOA.

Table 2. Magnitude of facilitations (msec) as a function of SOA for the Go/Nogo and the CRT task.

SOA	Go/Nogo Task	CRT Task	F
-400	-28.5	-49.8	9.2**
-300	-43.4	-52.9	3.4
-200	-45.5	-49.2	1.3
-100	-43.5	-43.4	0
-75	-45.3	-42.7	0.2
-50	-45.4	-35.5	14.6**
-25	-40.3	-33.9	3.7†
0	-38.9	-25.6	6.3*
25	-34.0	-21.6	15.1**
50	-23.7	-14.2	5.7*
75	-12.8	-8.6	0.6
100	-13.2	-4.7	6.4*
200	2.5	1.6	0.1
300	4.9	2	1.5

Note. The values of F obtained in statistical test of simple main effect. $^{**}p<.01$. $^{*}p<.05$. $^{\dagger}p<.1$.

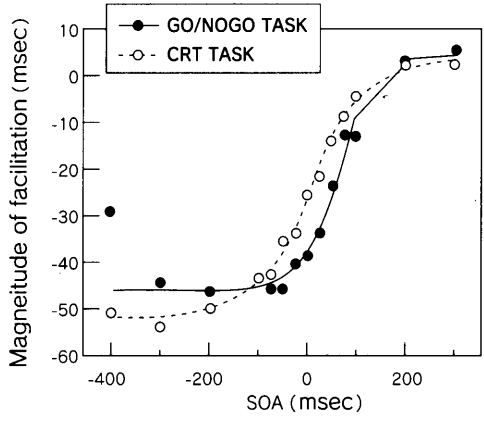

Fig. 2. Mean MFs as a function of SOA. A curve in this figure is a logistic function fitted to MF data for each task. The solid line is that for the Go/Nogo task, and the dashed line is that for the CRT task.

A solid and a dotted curve in Fig. 2 are logistic function fitted to MFs for each task. This sigmoid curve had a single point of inflection, and levels off at both extremes. This function is given by a following equation:

$$y = \frac{a}{1 - b \times \exp(x - c)}$$

The parameter a indicates the range of the MF varying as a function of SOA (x). The parameter b is called the slope coefficient: it indicates the steepness of the logistic curve. The larger the value of b, the slope of the curve will be more steep. The parameter c indicates a SOA point at the maximum rate of MF change, thus it also indicates the inflection point of the sigmoid curves. The curves in Fig. 2 were obtained in such a way; values of the parameters were calculated to give the "best fit" between the equation and the MF data. Table 3 showed mean values for each parameter among subjects. Pairwise comparisons between the Go/Nogo and CRT task were performed for each parameter. These analyses showed that there was a significant difference for b ($t = 2.63, p < .05$) and c ($t = 3.01, p < .05$), while there was no difference for a ($t = 2.19, p > .05$).

Table 3. Values of parameters for the Go/Nogo and the CRT task.

	Go/Nogo Task	CRT Task
a	-44.7	-52.6
b	0.042	0.021
c	45.0	3.1

Discussion

As in the previous studies (Bernstein et al., 1969a, 1969b; Nakano, 1995; Nickerson, 1970; Posner, 1976), the results of this experiment showed that the visual reaction time is facilitated by the presence of the near simultaneous auditory accessory. Figure 1 demonstrated that the RT continued to be decreased as the accessory preceding the visual target at least when the difference was less than 100 msec. It also indicated that the RT maintained the minimum value for few hundreds milliseconds in SOA. The goal of this study is to examine whether the magnitude of this intersensory effect is different between the Go/Nogo and CRT task. For this purpose, a magnitude of facilitation (MF) that is a RT difference between with- and without-accessory trials was calculated for each SOA point. Comparing these values between the two tasks revealed that the MFs was negatively larger at a range from -50 to 50 msec SOA in the Go/Nogo task than in the CRT task. The MF difference at this SOA range should be caused by a shifting of the logistic curve in the direction of positive SOA. The parameters in Table 3 confirm this inference. The parameter c indicates the inflection point of the logistic curve. The value of this parameter was larger for the Go/Nogo task. This result revealed that the mid-point of the sigmoid curve for this task shifted to the positive SOA direction. Furthermore, a trend of the curve was more steep for

this task as indicated by the parameter *b*. These facts revealed that the logistic curve for the Go/Nogo task started to be increased later than that for the CRT task. This finding supported the conclusion that the auditory accessory maintained the maximum effect in the Go/Nogo task, even when the accessory was presented close to the visual target.

Referring to results of Nakano (1997a), such the sustained maximum effect of the accessory was not caused by faster responses in the Go/Nogo task. Nakano (1997a) used a Go/Nogo task as in the present experiment, and manipulated an intensity of the visual target. Results showed that the SOA range of the maximum MF was longer when the visual intensity was low. In detail, the mid-point of the sigmoid curve was about 100 msec later in SOA for the low (5 cd/m^2) visual intensity than for the high (125 cd/m^2) intensity. This finding indicated that the SOA range of the maximum effect was not related to the difference of the response speed. Because in Nakano (1997a), the SOA range of the maximum MF was prolonged in the low visual intensity while the mean RT for without-accessory trials was longer about 10 msec than in the high intensity. On the other hand, RT in the Go/Nogo task was shorter than that in the CRT task.

The parameter *a* is a range of the MF variation. This value indicated the maximum MF, because the logistic curves converged to 0 msec at positive SOAs. As in Table 3, the parameter *a* was not significantly different between the two tasks. This result showed that the type of RT task did not influence the maximum MF. Contrary to this result, Bernstein et al. (1969a, b) showed that the maximum MF was as much as 23 msec larger in the Go/Nogo task than in the CRT task. This discrepancy between the present and the Bernsteins' result was caused by differences in following two experimental settings; a SOA range and a FP. At first, the SOA range in the Bernsteins' experiments was not sufficient to observe the maximum facilitation. They examined the facilitation effect at the range from 0 msec to 90 msec (Bernstein et al., 1969a) or to 190 msec (Bernstein et al., 1969b). So they did not present the auditory accessory before the visual target, that was expressed by negative SOAs in this experiment. In such the SOA setting, the maximum MF appeared at 0 msec SOA. The present study, however, showed that the MF at this SOA point did not represent the maximum facilitation, because the RT continued to be decreased around this SOA point. Furthermore, this decreased tendency of the RT was more steep in the Go/Nogo task than in the CRT task (Fig. 2). Such the difference in RT decreasing should produced a (negatively) larger MF. In fact, Table 2 showed that the MF at 0 msec SOA was 13.3 msec larger in the Go/Nogo task than in the CRT task. The most important result in this experiment was that there was no significant difference in the MFs as far as it kept the maximum facilitation (Table 2). This finding indicated that the MF difference found by Bernstein et al. appeared at a limited SOA range, and it should be disappeared when the MF reached the maximum value.

The second reason that caused the MF difference in Bernsteins' studies was settings of the FP. The experiment in which they examined for the Go/Nogo task (Bernstein et al., 1969a), the FP was randomly varied in two of three subjects. While in the CRT task (Benrstein et al., 1969b), they employed a constant 2 sec FP in all four subjects. The important fact is that the randomized FP increased the facilitation effect (Sanders,1980). Thus in Bernsteins' studies, it is most likely that the randomized FP in the Go/Nogo task made the MFs larger than in the CRT

task. In conclusion, there are two factors that have caused the larger MF in Bernstein et al. (1969a). First is the steepness of the RT decreasing, and second is the randomized FP.

The results of this experiment indicated that the degree to which the accessory facilitated the RT was not differ between the Go/Nogo task and the CRT task. The principal finding was that the Go/Nogo requirement prolonged the SOA range of the maximum facilitation. This result was not caused by faster responses under the Go/Nogo situation. One possible factor influencing the maximum facilitation is demands of response selection. Under the Go/Nogo requirement the subjects know the response hand before the presentation of the visual target. While in the CRT task, they choose the response quickly after evaluating the target. Such the loading on the response selection reduced both the range and the magnitude of the maximum facilitation. For example, when stimulus - response mappings are incompatible (i.e. right hand response to a visual target on left hemifield), the magnitude of the maximum facilitation was reduced (Nakano, 1997b). Previous studies suggested that the demands of the response selection also reduced it comparing to the Go/Nogo requirement (Sanders, 1980; Welch & Warren, 1984). This study revealed that such the demands specifically reduced the SOA range of the maximum facilitation and not reduced the magnitude of it.

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